# The Edge Completes the Cloud: A Gartner Trend Insight Report

**Published:** 14 September 2018 **ID:** G00360847

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Edge computing delivers the decentralized complement to today's hyperscale cloud and legacy data centers. To maximize application potential and user experience, EA and technology innovation leaders need to plan distributed computing solutions along a continuum from the core to the edge.

## Opportunities and Challenges

- Edge computing addresses the limitations of centralized computing (such as latency, bandwidth, data privacy and autonomy) by moving processing closer to the source of data generation, "things" and users.
- Edge computing augments and expands the possibilities of today's primarily centralized, hyperscale cloud model, supports the systemic evolution and deployment of the IoT, and supports entirely new application types, enabling next-generation digital business applications.
- Although today's hyperscale cloud computing delivers massive, centralized scale, edge computing requires management and security across a massively distributed scale.

## What You Need to Know

- Cloud computing and edge computing are complementary, rather than competitive or mutually exclusive. Organizations that use them together will benefit from the synergies of solutions that maximize the benefits of both centralized and decentralized models.
- Edge computing will take place at the absolute edge, and it will be leveraged anywhere in a distributed computing architecture that meets use case requirements for latency, bandwidth, data privacy and autonomy.
- For enterprises to capitalize on the data and business insights of IoT, analytics will need to be closer to the edge for near-real-time feedback and business process optimization, and to avoid the costly impacts of latency and insufficient bandwidth.

- Enterprises' IT and OT organizations are on a collision course with legacy investments and architectures and the conflicting objectives dividing them. Technically, IT and IoT can augment what OT does today.
- As cloud and IoT become more integrated and critical, businesses must plan for IT/OT alignment in architecture, governance and security, as well as infrastructure specification and acquisition.

## Strategic Planning Assumptions

By 2022, more than 50% of enterprise-generated data will be created and processed outside the data center or cloud.

By 2020, 80% of asset-intensive industry CIOs will be responsible for operational technology (OT) data, and will embrace IT/OT integration as a strategic imperative.

## Insight From the Analyst

### Cloud and Edge — Better Together

Bob Gill

Research Vice President

The rise of edge computing will come as no surprise to anyone following computing architectures during the past 40 or more years. We have gone through spasms of centralization to scale up processing power, through a phase of decentralization to allow real-time, distributed computing, flexibility and agility. Then we've gone right back to centralization, with massively scaled hyperscale cloud data centers.

Edge computing is a decentralized swing of the pendulum, with a difference. We believe the gravity (benefits) of the cloud to be so great that the pendulum simply stops. The decentralized swing wasn't forced by any failures of the cloud to deliver; it was driven by opportunities for entirely new applications that can't abide the latency to and the cost of the cloud, as it's normally delivered today. In the pendulum's place, we envision a continuum of centralization, with solutions that make use of both core and edge resources delivering capabilities more powerful than anything we've ever seen.

A bit of hyperbole? Perhaps. However, consider the ever-increasing compute power and richness of application services offered by the hyperscale cloud. Then, multiply it by millions or even billions of

remote nodes, many with their own compute power and the ability to interact with the physical world around them. Imagine these distributed nodes and their context-specific interactions achieved through sensors, combined with distributed machine learning and analytics, learning, processing and reacting locally. At the same time, they're taking advantage of the core to further analyze the data and activities of the multitude of connected devices as a whole.

Is this purely aspirational, a wild idea from a tech researcher, or science fiction? None of the above. A teenager with a credit card can begin building such cloud-integrated edge solutions today. So enterprises certainly can as well. Although the patterns are nascent, and the technology is perhaps not yet industrial strength, they will be. Soon. Welcome to the conjoining of the edge and the cloud.

Why should enterprises care? Digital business relies on the convergence of the physical and the digital to create new business opportunities and new business moments. It benefits from edge. The Internet of Things (IoT) uses edge design patterns for architecture. Cloud computing will benefit from augmentation by the edge. Enterprises are using edge topological ideas to cut WAN costs by half, while improving resiliency and improving user experience (UX) by 200%. Enterprises are using the edge model to create value from data and observations, just as digital business promised we would.

In short, edge computing lets us thumb our noses at the speed of light, and work around it to expand the reach and capabilities of IT. By allowing core-based applications to integrate with edge devices and their far-flung sensors and intelligence, many of them are generating huge amounts of data. That's what it's all about — enabling newly possible, distributed, external-world-interacting applications by simply adding topology to the plethora of emerging, edge-supporting technologies.

In this research, we explore:

- The potential for edge computing
- What edge computing is, and which technologies help shape it
- Whether enterprises are ready for edge computing
- How will the edge and the cloud will evolve together

Bob Gill

## Executive Overview

### Definition

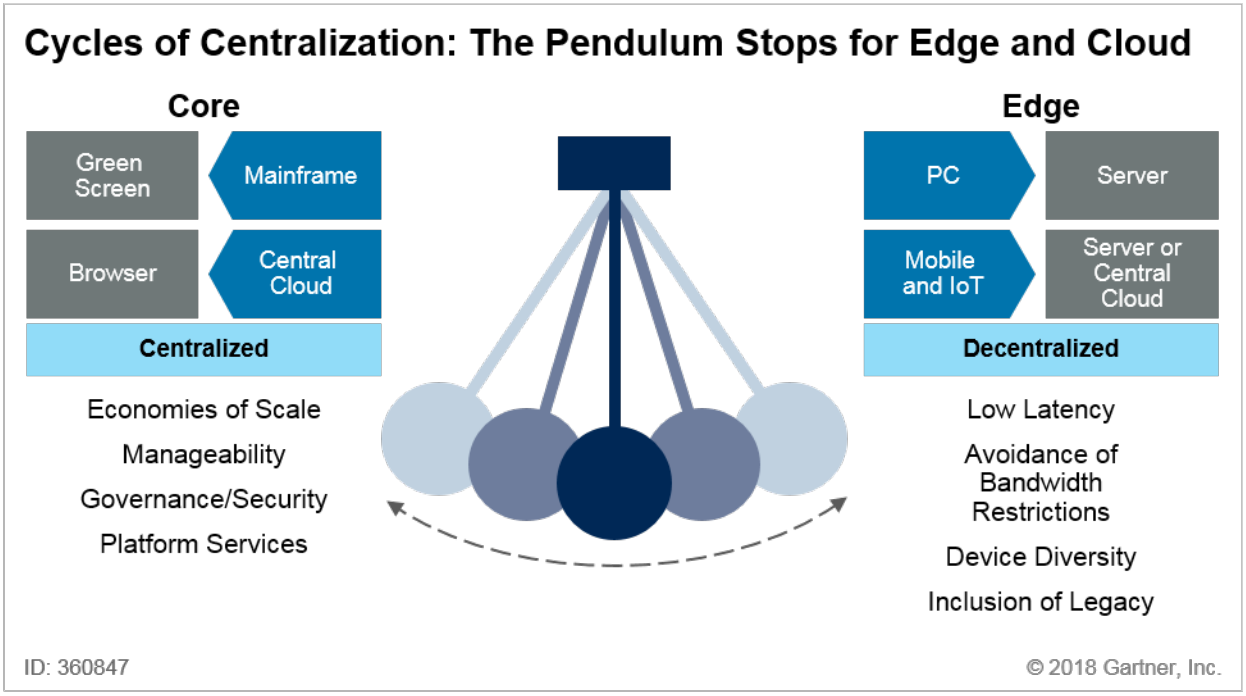
Although the topological concept of edge computing may be decades old, the limitations imposed by the centralized implementation of hyperscale cloud and the rise of investment in the IoT has thrust edge topology into the limelight. Edge computing places content, data and processing closer to the applications, things and users that consume and interact with them. It takes the classic IT workload quandary of "What goes where?" and encourages workload and capability placement that

optimizes the balance of latency, bandwidth, autonomy and security across a continuum of options, from hyperscale cloud data centers to home thermostats.

Edge computing doesn't compete with cloud computing, per se, but it will complement and complete it. It's important to discuss what the "edge" really is, and what is meant by "edge computing." The description of a decentralized edge location implies a centralized alter ego (i.e., the "core"). This is a centralized data center, ranging from a hyperscale cloud provider with massive data centers, to individual enterprise data centers of all sizes.

The "where to store and process the data" pendulum (see Figure 1) has swung between highly centralized approaches (such as mainframes or centralized cloud services) and more-decentralized approaches (such as PCs, mobile devices and people). Distributed deployment models are best for addressing connectivity and latency challenges, bandwidth constraints, and the greater processing power and storage embedded at the edge.

Figure 1. Cycles of Centralization: The Pendulum Stops for Edge and Cloud



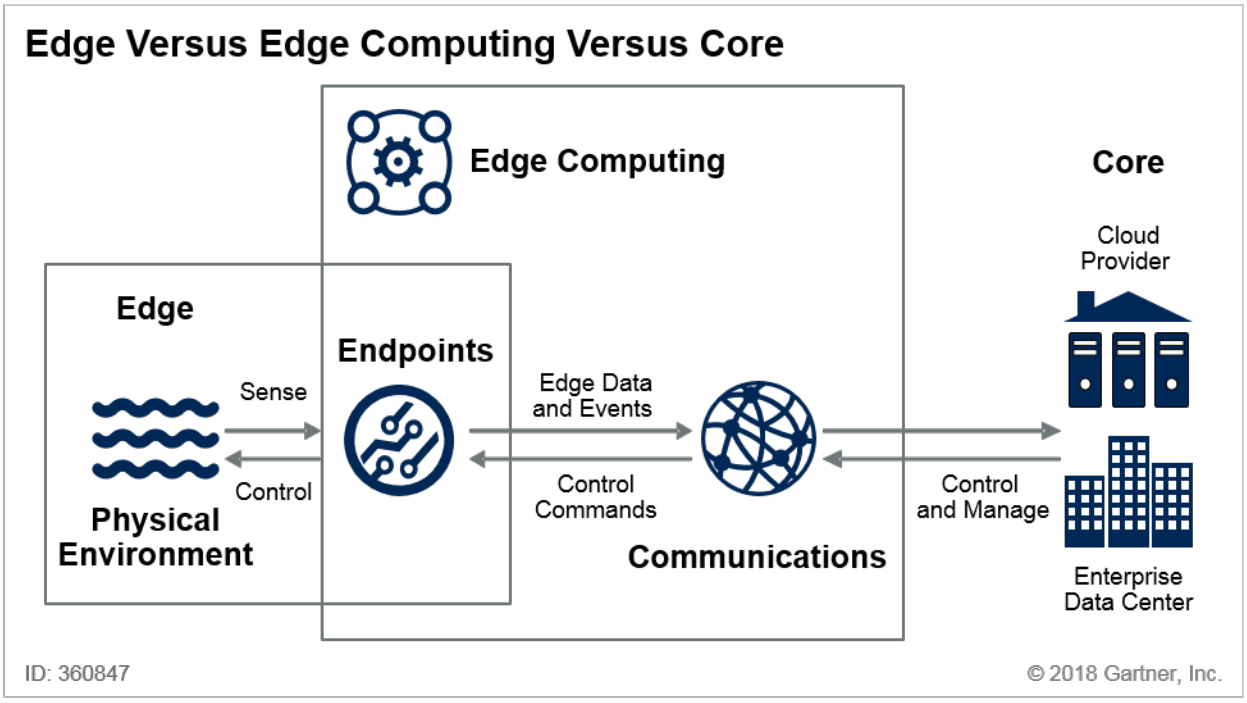

Source: Gartner (September 2018)

In this report, we highlight relevant research to define edge computing, discussing its benefits and synergies with IoT, and how the edge as a topological construct fosters new thinking about application architectures and network design. Finally, we describe how the edge is positioned as the fulfilling complement to centralized hyperscale cloud (see Figure 2):

- **The Edge:** The physical location where things and people connect with the networked digital world

- **Edge Computing:** A part of a distributed computing topology in which information processing is located close to the edge — where things and people produce or consume that information
- **The Core:** A centralized data center owned by an enterprise, a service provider or a cloud provider

Figure 2. Edge Versus Edge Computing Versus Core




Source: Gartner (September 2018)

Neither deployment at the edge, nor IoT require edge computing. For example, a sensor can stream its data to a central cloud data center, and analytics can take place there. If the sensor is connected only to a local computing device — a PC, a PLC on an assembly line, or a self-driving and autonomous car — then the sensor is not at the edge of anything. It's just a sensor, sending data to a local computer with which only local users can interact. In other words, it enables local computing as part of an autonomous embedded system.

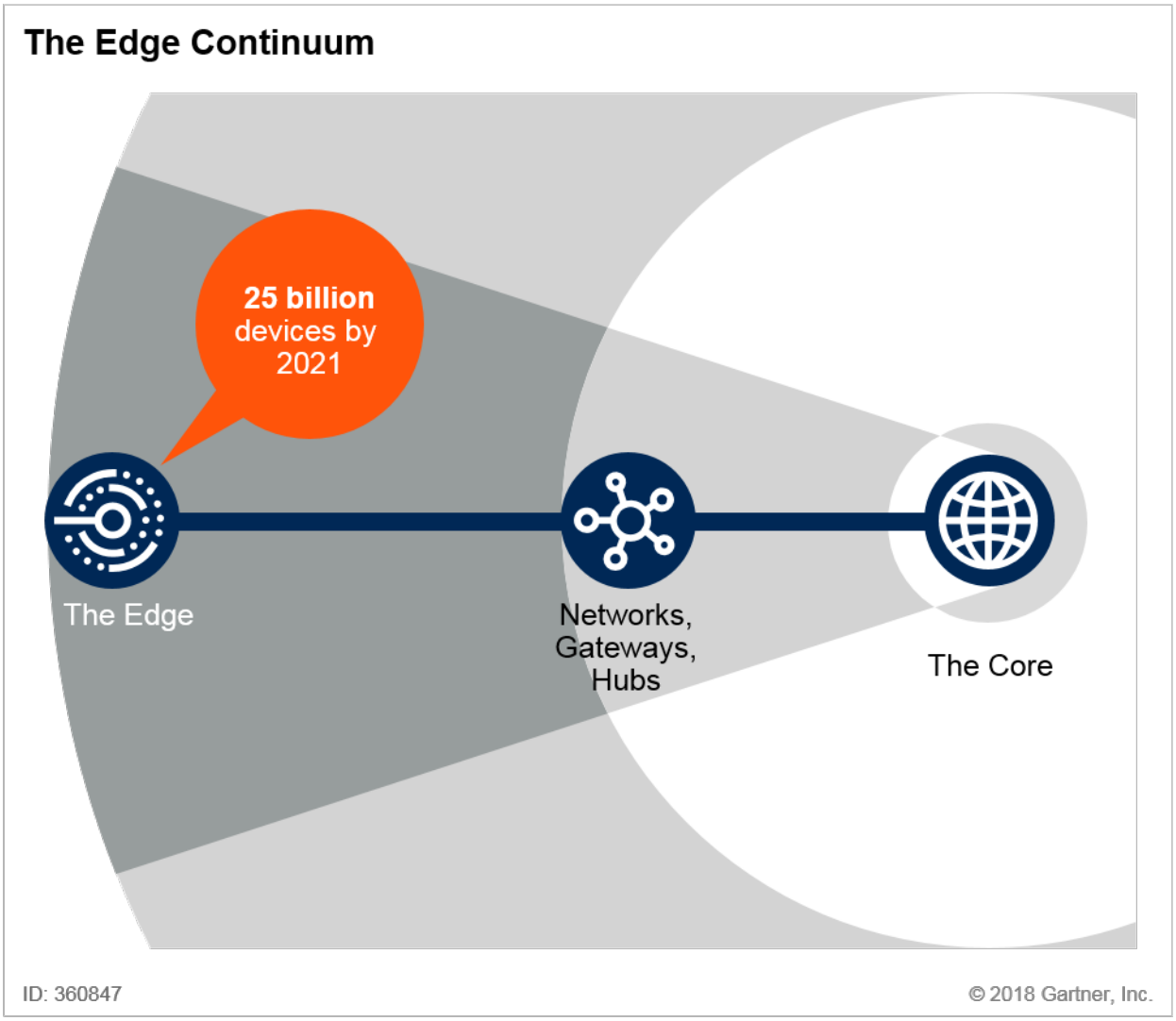
Likewise, if a person is interacting with a computing device — doing word processing or creating art using virtual reality tools with a headset and a PC — this also isn't the edge of anything. Or, if a person is using a connected smartphone for e-commerce, or to see augmented information about a physical object (or catching Pokémon), they are on the edge of a networked digital world. On a broader scale, a hyperscaler might place several megawatts of communication nodes in a distributed data center to extend their reach closer to concentrations of users and consider that an edge node.

# Research Highlights

## Why Edge? — The Barrier-Breaking Power of Topology and the Potential of Edge Computing

Edge computing is not a technology looking for a market, but a topology and design being fulfilled with technologies such as IoT and the cloud to enable new solutions. In particular, edge topology supports the placement of computing along a continuum that ranges from a centralized isolated data center at one extreme, to an edge device equipped with machine learning and analytics capabilities closer to the edge. By moving data and processing power closer to creators and users of content, whether people, applications or things sensing their environments, we maximize or balance the degree to which each of the edge's attributes (see Figure 3) is satisfied.

Figure 3. The Edge Continuum




Source: Gartner (September 2018)

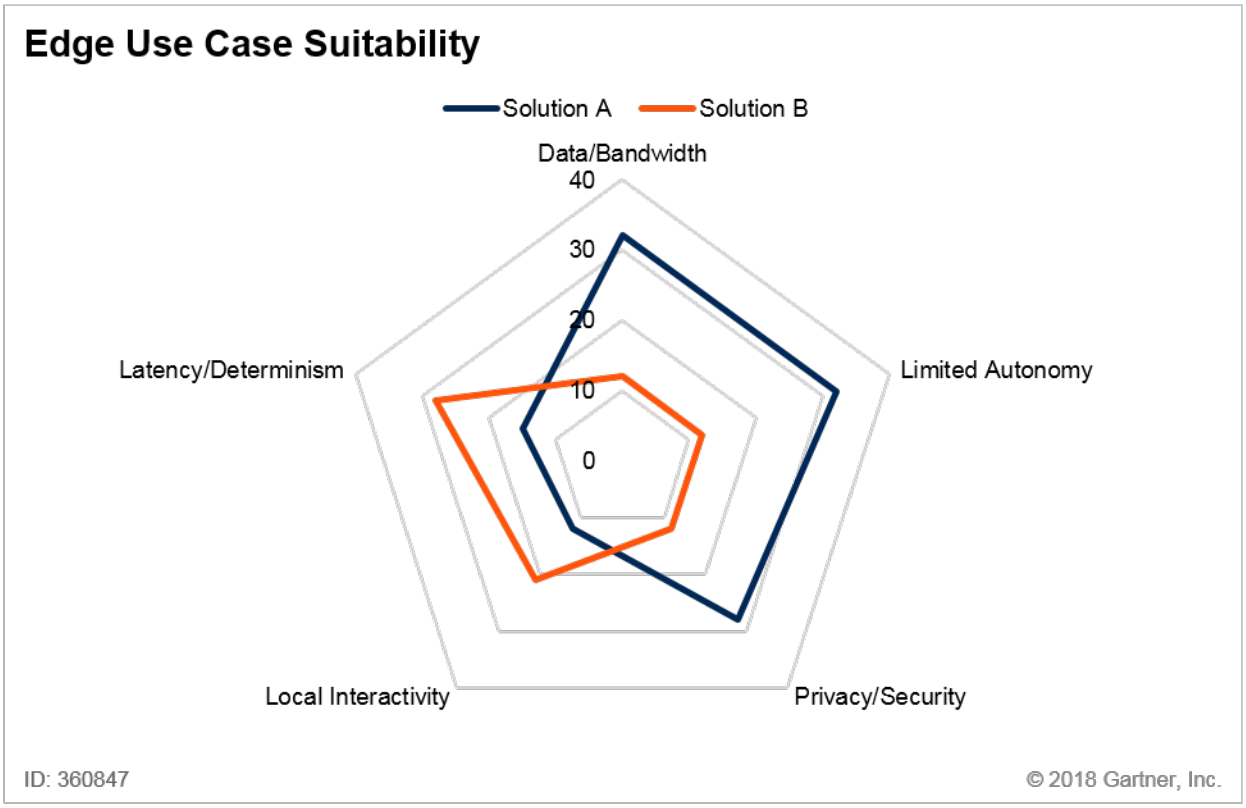
By moving data and processing power closer to creators and users of content, whether people, applications, or things sensing the environment around them, we can balance the degree to which each of the five attributes of edge is satisfied.

Although the avoidance of latency is the most widely cited reason for placing workloads at the edge, there are many benefits, and some of the nuances are subtle. We use five different categories of benefits, or imperatives of the edge, to determine how beneficial edge computing may be for a given application. We group these imperatives as:

- Data volume/bandwidth considerations
- A need for limited autonomy or disconnected operation
- Privacy and security concerns
- A requirement for local interactivity
- The effect that latency may have on an application

As we show in Figure 4, differing use cases may have differing requirements for each of these five attributes. If an application or use case scores low on all five attributes, then the designer may want to reconsider why the edge is being considered.

Figure 4. Edge Use Case Suitability




Source: Gartner (September 2018)

The research in this section focuses in detail on the definitions and drivers for edge computing, including the role of the edge in enabling digital business. We pay particular attention in this report to the recent research on IoT architectures and organization issues, because early pioneering work on IoT has presaged and included many of the elements of edge computing as well.

## Related Research

"How Edge Computing Redefines Infrastructure"

The research provides the consensus definitions of the terms "edge" and "edge computing," as used across Gartner. The edge can be thought of as a specific place where devices and systems bridge the gap from the physical world and sensors, to a digital world of computing and communications. We can be sufficiently broad to describe the benefits of topology, while digging deeper into technology to describe what an application needs to be "edge-capable."

"Edge Manifesto 2018: Topology Trumps Technology"

This is a refresh of a year-old report that first discussed the concept of the edge and the reasons edge computing was inevitable. It drives home the point that the edge is, first and foremost, a description of topology — i.e., where computing elements are in relation to each other, and the

systems that can be built uniting core and edge. It also goes into greater depth about applications that may have little compute involved, and most closely resemble brick-and-mortar versions of content delivery networks (CDNs) for applications such as the local delivery of over the top (OTT) video on demand.

“The Future Shape of Edge Computing: Five Imperatives”

This research highlights how latency and determinism, local interactivity, limited autonomy, data and bandwidth, and privacy and security imperatives will help shape how edge use cases are leveraged. Solutions and markets will form around combinations of these imperatives, while you can use them to evaluate the efficacy of a possible edge computing solution.

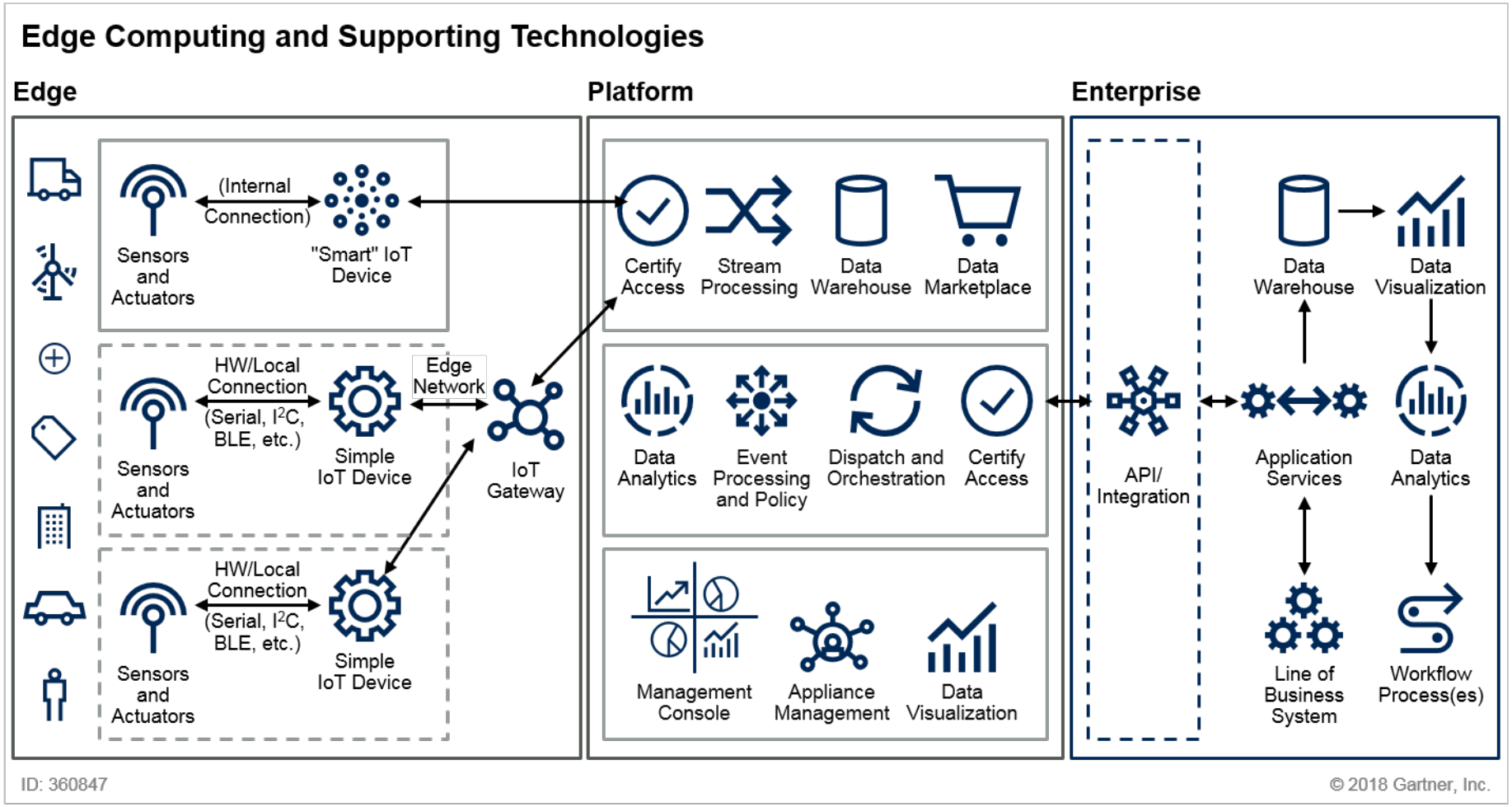
“Unlock Digital Business Value Through the Economics of Connections”

This and other research (see “Hype Cycle for Enterprise Architecture, 2018”) represent the technology-enabled business discipline of creating value from an increasing density of connections among people, business and things in the world of digital business. Gartner believes the economics of connections is a viable, but still emerging framework for planning and exploiting digital business. Creating ecosystems, embracing economic agents, and measuring and monetizing connections will prove more complicated in digital businesses.

## Is Edge Computing a Topology or a Technology, or What? Which Technologies Enable and Shape Edge

Fundamental to the Gartner position on edge computing is that topology trumps technology when it comes to composition. “Location,” such as the number and optimal placement of workloads and content, is so critical to edge architectures (see Figure 5) that incredibly valuable solutions have been built, using little or no technology, beyond physical cross-connects. The edge is a topological concept. However, technological advancement at the edge (e.g., IoT “things”), in the network between edge devices and core (e.g., gateways and hubs), and at the core itself (e.g., hyperscale cloud providers’ products), enables developers/users to deliver demonstrable value from the topology.

Figure 5. Edge Computing and Supporting Technologies

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## Related Research

"Technology Insight: Edge Computing in Support of the Internet of Things"

This research reveals that every endpoint must now be treated as an extension of the data center or the cloud. Edge computing solutions vary from basic event filtering to complex or batch processing. Systems require adequate computing power to address those requirements, based on the number of endpoints, location, topology, volume and the velocity of data generated, as well as the type of processing required at the edge.

"Market Guide for Edge Computing Solutions for Industrial IoT"

Edge computing solutions in industrial settings are poised for rapid growth and innovation, driven by the need for real-time insights and localized action. This requires partnerships to deliver reference architectures that address one or more use cases at the edge in verticals, such as manufacturing and retail, energy and utilities, building management, public infrastructure, and transportation and logistics.

"Hype Cycle for Infrastructure Strategies, 2018"

Tracking changes in IT infrastructure, Gartner's latest Hype Cycle details a number of edge, bimodal and software-defined innovations, as well as cloud- and container-based delivery strategies that are moving up the curve. Infrastructure and operations (I&O) leaders should expect to see continuing disruptions. The IoT and edge computing continue to deliver new technologies that require development, deployment and management, where old approaches fall short or are incomplete.

"Hype Cycle for the Internet of Things, 2018"

Tracking changes in technology adoption explicitly in the IoT, this Hype Cycle looks at those technologies and services that make up the extended IoT ecosystem. Although edge architecture in support of the IoT is well-accepted, technologies offering higher-layer-specific solutions, such IoT business solutions, managed IoT services and IoT edge analytics, are still early on the curve. There will continue to be moderate churn and change, as standards evolve and early solutions succeed or fail.

"2018 Strategic Roadmap for Compute Infrastructure"

As industries are reshaped by digital business initiatives that are gathering momentum, businesses must revisit their compute, virtualization and software environments. With a focus on increasing

intelligent management, efficiency, agility and elasticity, while decreasing complexity, migration plans must increasingly take advantage of edge and cloud use cases.

“2018 Strategic Roadmap for Storage”

Gartner sees two major external forces having a meaningful impact on enterprise storage infrastructure: a move to public cloud at the executive level and an increase in risk tolerance when pursuing agility. Data centers must be modified to tolerate latency-sensitive workloads, back up from the cloud and the IoT, and they need to be more flexible toward further changes in how information is processed.

“Edge Computing Challenges Go-to-Market Strategies in IoT”

This research details how growing interest in IoT is raising awareness and demand for edge computing among end users. This, in turn, drives them to query their incumbent providers about how they will evolve to support edge computing, at the product level and in terms of go-to-market (GTM) strategies. Among the affected vendors, there is a real chance that the ones unable to demonstrate and deliver edge capabilities to end users will not be able to exploit the IoT opportunity.

“Market Guide for CSP Edge Computing Solutions”

Cloud service providers (CSPs) will be key players in cloud and IoT deployments, as 5G mobile networks take off. They will need to keep customers and prospects in the loop, highlighting a logical upgrade roadmap to keep up with distributed cloud opportunities, while ensuring interoperability and security.

“Magic Quadrant for WAN Edge Infrastructure”

The WAN edge infrastructure market has evolved from traditional branch routers, and is undergoing dramatic change, driven by the needs of digital business transformation and the demands of line of business (LOB) managers. This market transition has seen the influx of incumbent and emerging vendors from multiple markets — e.g., routing, security, WAN optimization and software-defined wide-area networks (SD-WANs), each bringing its own differentiators and limitations. Gartner often sees two or three incumbents and one or two emerging vendors competing for each customer opportunity. As a result, we have created the first Magic Quadrant to cover this market.

“Why and How to Design Digital Twins”

Digital twins are proliferating in the IoT for many different uses. They provide a design that decouples each system from the physical thing, making it easier to change one without changing the other. This reduces communication overhead and data redundancy when multiple systems interact with the same thing.

“Use the IoT Platform Solution Reference Model to Help Design Your End-to-End IoT Business Solutions”

To succeed in IoT implementations, businesses must thoroughly examine and understand the full composition of end-to-end IoT business solutions, the role of IoT platforms within them and the appropriate IoT platform deployment models. Gartner's reference model highlights essential, distributed, IoT platform suite functional capabilities.

"Competitive Landscape IoT Platform Vendors"

This research highlights how an overabundance of vendors and turbulence across the IoT platform market demonstrate a need to drive clear product differentiation and to invest in an effective go-to-market strategy to reach customers with a clear message. A range of scenarios, from best-of-breed to trusted partners, whales and minnows, or a "zombie apocalypse," could affect marketing requirements and how customers will choose their IoT and edge solutions.

"Magic Quadrant for Industrial IoT Platforms"

This Magic Quadrant furthers the platform discussion, and illustrates the emerging mix of players in this software market, ranging from consultancies and IT system vendors, to those from the industrial or OT world. This research shows that adoption is growing, but the installed base of complex IT/OT integration is small and focuses on narrowly defined outcomes. We urge enterprises to focus on integration, as well as data and device management, to ensure that platforms scale with needs.

"Market Guide for Industrial IoT Gateways"

Industrial IoT gateways are transitioning from simple devices that bridge OT and IT networks to intelligent edge computing systems that can learn, react and control edge networks. This guide highlights the need for modularity and a focus on gateways meeting specific safety, security and performance requirements for each use case.

"Decide If You Should Use Containers for Your IoT Project"

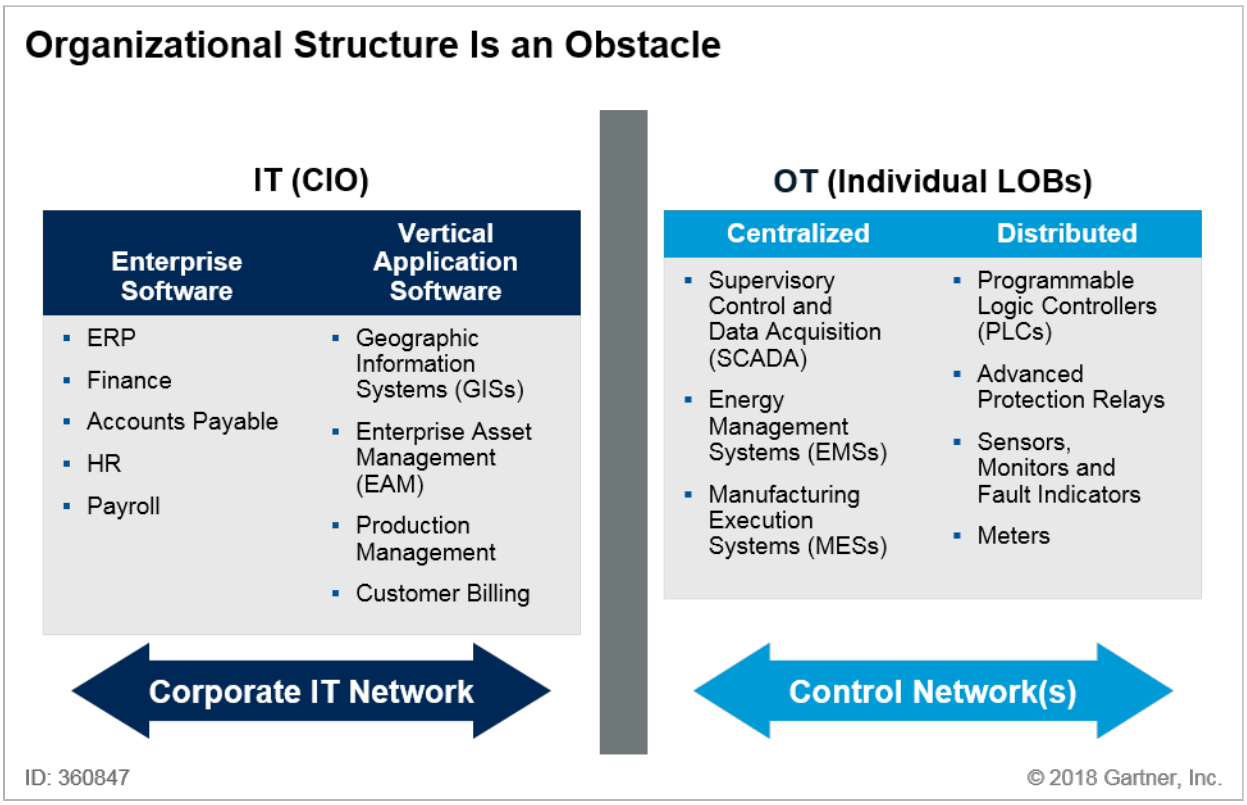
Container-based services, such as Docker, have emerged on the IT scene just as we see IoT and edge-based services requiring flexible endpoints and gateways over a geographically distributed environment, creating another decision point. Businesses can use containers as a building block for application management in large-scale "greenfield" IoT projects, extending enterprise DevOps best practices to such initiatives. They can use containers for their ability to make incremental updates to applications hosted with a private container registry close to the edge infrastructure to address regulatory compliance requirements.

## Are Enterprises Ready for Edge Computing? Is It Feasible to Deploy? What Are the Organizational and Technological Complexities?

The rise of cloud computing has exposed and widened the organizational disconnects between the IT organization and the business units it supports (see Figure 6). IT often focuses on the infrastructure it has built and the potential for efficiencies using the cloud. Business units have latched onto the higher-layer platform services and functionality, as well as the development models of platform as a service (PaaS). They are dragging the cloud infrastructure "along for the ride." This IT-versus-business unit misalignment is likely to grow with IoT and edge computing, which looks to

integrate devices owned and managed by different groups, and mixes a desire to create cutting-edge applications using an installed legacy of vertically optimized solutions. Suddenly, Mode 1 legacy devices must be integrated into future-facing Mode 2 applications.

Figure 6. Organizational Structure Is an Obstacle




Source: Gartner (September 2018)

By 2020, 40% of IT operations teams will have driver, implementer or operator responsibility over their organizations' IoT initiatives, which is an increase from 5% in 2018. Assuming there is significant value in the data created by the IoT, questions such as who owns the data, what platforms it's on, and how it's stored and processed will be fundamental. However, to date, there is little agreement on how to integrate IT and OT to unlock the full potential of the IoT.

Questions arise over who specifies, controls and manages the deployment of devices at the edge to ensure synergies with the data and analytics, as well as the overall digital business plan. Although a closed stack, end-to-end system deployed by a hyperscaler could pre-empt this pain, what do we do with the billions of dollars of embedded systems and factory equipment already installed? How do we build new multivendor solutions? Who's "in charge"?

By 2020, 40% of IT operations teams will have driver, implementer or operator responsibility over their organizations' IoT initiatives, which is an increase from 5% in 2018. How can IT and I&O leaders drive consistent overall edge architectures to ensure that future synergies, rather than silos, will be achieved?

## Related Research

"I&O Leaders Must Get Involved With Current or Planned IoT Initiatives"

IoT projects that begin in the LOB or operations units without IT involvement can cause major challenges for I&O leaders, when these pilot projects expand into production environments. I&O must be on hand to provide integration, communications, analytics and underlying infrastructure.

"Operational Technology in Digital Business: What the Board Needs to Know"

Asset-intensive companies can transform from disconnected or minimally integrated IT and OT environments into integrated businesses. This research can assist a CIO presenting to a supervisory board of directors to better inform them about the opportunities that OT integration might bring to a company.

"2018 Strategic Roadmap for IT/OT Alignment"

IT and OT continue to clash, with organizational and cultural barriers and conflicting objectives between them. As the cloud and the IoT become more popular, businesses should plan for IT/OT alignment in areas of architecture, governance, security and software management, infrastructure, support, and software acquisition.

"Show the Value of OT and IT Alignment, and Realize Digital Business Results"

OT vendors typically differ from IT vendors in their approaches to architecture and security. Arriving at a mutually beneficial compromise is a necessary process for CIOs and their organizations. This requires them to determine the data needs of the IT and OT systems and processes. Joint integration plans between IT and OT where data flow benefits need are realized need to be created.

"How to Mitigate Software Licensing Risk From Edge Computing"

There are four key risks to edge computing: software entitlement risk, unauthorized edge consumption, lack of visibility and the risk of indirect access. Many teams exploring edge technologies are unaware of these risks, and the potential for fines and penalties due to infringing license terms.

"Build a Flexible, Multivendor Architecture to Address Your Enterprise IoT Needs"

No single IoT technology vendor can single-handedly support a complex enterprise IoT project, resulting in a multifaceted, multivendor IoT environment. To address, this, businesses must assemble a project matrix list of use cases that reflect targeted business outcomes, and align the architecture with asset, budget and technology requirements.

“Getting Started: How to Strategize, Prepare, Plan and Manage Enterprise IoT Projects”

In this research, Gartner offers a framework of best practices for enterprise IoT journeys. It will assist CIOs when launching and optimizing an enterprise IoT or industrial IoT (IIoT) project, as the number and range of IoT connected products increase dramatically. This will be accompanied by growth in the type and style of IoT networking technologies.

“Solution Path for Developing an Internet of Things Technical Strategy”

IoT demands a technical strategy that enables organizations to rapidly implement IoT solutions. Gartner’s solution path can help identify business needs, and use them to drive technical strategies.

“Effective Internet of Things Planning and Design”

IoT solutions consist of many critical parts, making them likely to be the most complex systems organizations will plan, build and operate. Businesses must manage the inherent complexity of the IoT. They will be tooling up not for a single solution, but for the construction, deployment and operation of a stream of IoT projects. Gartner recommends a “think big, start small, move fast” philosophy.

“How to Increase Uptime With Scaled-Down Remote Office Infrastructure”

The competing pressures of increasing availability and controlling costs drive enterprises to smaller IT architectures, operating at geographically dispersed locations in remote and edge environments. Hardware represents up to 80% of infrastructure costs, so virtualization is key to creating cost-effective infrastructure in remote sites.

“IoT Solutions Can’t Be Trusted and Must Be Separated From the Enterprise Network to Reduce Risk”

Gartner predicts that approximately 20 billion new IoT devices will be connected by 2020. We see many of them creating an ever-increasing attack surface for IT. Businesses must discover, classify, segment and provide continual monitoring to protect their networks, which will be at constant risk.

## If the Edge Completes the Cloud, Then What’s the Cloud’s State in Late 2018?

The cloud has moved beyond just disrupting IT to providing the underlying basis for most future digital disruptions and future innovations. The cloud exists on a spectrum (see “Four Types of Cloud Computing Define a Spectrum of Cloud Value”), and supports the next-generation platforms on which new IT capabilities are being built.

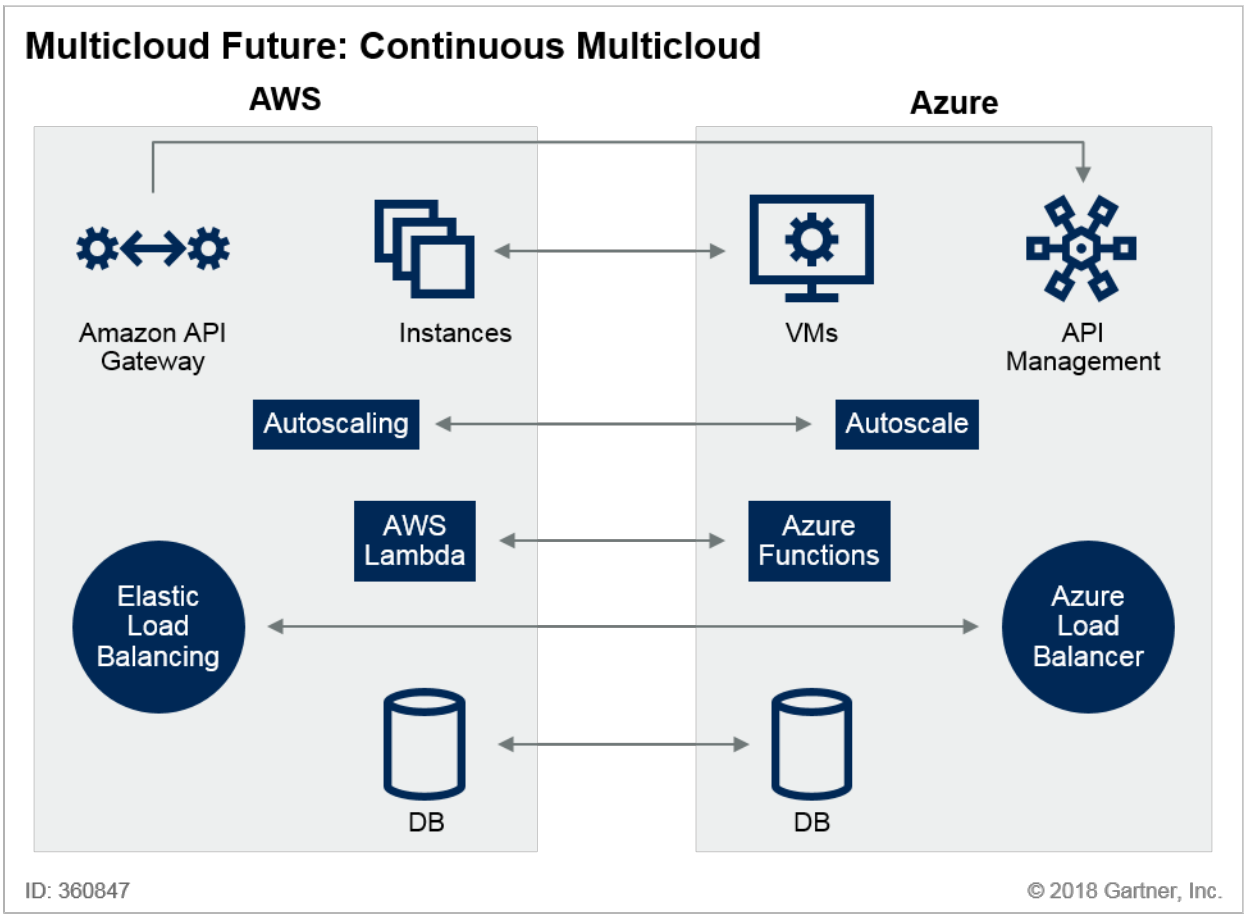
In 2019, the lines between infrastructure as a service (IaaS) and PaaS will continue to blur. Organizations will need to develop the right strategies for deciding how to place/build an app on the right services, and manage across all IaaS/PaaS on a multiprovider basis

As cloud computing becomes mainstream, many organizations find that their IT environments include public and some private cloud, alongside traditional IT systems. Most organizations believe hybrid scenarios will help address the challenges of these disparate environments. Our recent cloud Hype Cycle noted the following patterns:

- The next wave of cloud disruption (cloud-enabled platform services) is delivering advanced capabilities around artificial intelligence (AI), blockchain, the IoT and so forth.
- At the peak (serverless, multicloud and containers), much of the excitement is around specific approaches that are driving innovation.
- At the trough, concepts that have generated significant excitement in past years (private cloud, cloudbursting and brokerage) are struggling with implementation challenges.

Although the cloud is becoming mainstream, that does not imply that all workloads will be placed in the cloud during the next decade or so. Technical incompatibilities, decades of embedded business logic in mainframe applications, government regulations and simple economics all conspire to keep some workloads out of the cloud, driving us toward a hybrid cloud/noncloud future. On the device front, the billions of controllers and devices already deployed cannot and will not be upgraded or swapped out to support end-to-end cloud stacks. More than in general-purpose applications, the edge and the IoT imply a heterogeneous, multicloud design for the future (see Figure 7).

Figure 7. Multicloud Future: Continuous Multicloud




Source: Gartner (September 2018)

Gartner research on cloud computing and its impact on enterprises is broad and deep. In particular, the merging of IaaS and PaaS functionality has drawn firmer boundaries between use cases that support infrastructure efficiencies, based on basic compute, storage and networking, and business-focused, solution-oriented services, such as databases, analytics and process integration. The specialized nature of many of these services implies a measure of enterprise lock-in for those that adopt them, as well as a corresponding need for heterogeneous multicloud deployments, to obtain the best mix of services possible across the enterprise. Here, we describe the synergies of these advances in the cloud, with the scope and reach of edge computing.

## Related Research

“Market Trends: The Convergence of IaaS and PaaS Cloud Services”

As IaaS and PaaS become a combined service model, the trend toward single, consistent and modular offerings creates new challenges. The validation of the converged service model demonstrated by market adoption implies ongoing change and disruption for traditional IaaS and

PaaS technology and service providers. The boundaries between “infrastructure” and “platform” are blurring, leaving these terms to collapse into a single, continuous spectrum of services.

“The Key Trends in PaaS, 2018”

The cloud as a strategic platform for innovation in digital business leaves application leaders facing decisions on application architecture and platform infrastructure. They must understand the key trends in PaaS, and embrace it to maximize their business agility. They also need to modernize to embrace IoT and innovation in cloud services.

“Magic Quadrant for Cloud Infrastructure as a Service, Worldwide”

The cloud IaaS market is consolidating rapidly. Customer expectations continue to escalate. Customers now expect cloud IaaS providers to offer a broad array of services that encompass hardware infrastructure; software infrastructure; management and governance capabilities; and preintegrated, value-added solutions. Moreover, they expect providers to have robust ecosystems for managed and professional services, as well as a software and tools ecosystem. Providers need to achieve breadth and depth of capabilities with a global platform deployed at scale; otherwise, they’ll be forced into a niche.

“Critical Capabilities for Public Cloud Infrastructure as a Service, Worldwide”

As public cloud IaaS moves into the mainstream, evaluators quickly find that public cloud IaaS is not a commodity, and providers differ enormously on the depth and breadth of their capabilities. This Critical Capabilities research compares providers’ abilities to deliver value for five common use cases for public cloud IaaS. This can help you draw up a shortlist of appropriate providers for public cloud IaaS use cases in your organization.

“Technology Insight for Multicloud Computing”

Most organizations will pursue a multicloud strategy, although most will also designate a primary cloud provider for a particular purpose, and are likely to have 80% or more of those types of workloads in their primary provider. Because most organizations will have a multicloud strategy, they will also need to implement multicloud management to achieve some degree of common governance and tooling for those multiple cloud providers.

“2019 Planning Guide for Cloud Computing”

In 2019, the lines between IaaS and PaaS will continue to blur. Organizations will need to develop the right strategies for placing or building applications on the right services, and managing across all IaaS and PaaS on a multiprovider basis. This research highlights the trends as cloud computing becomes ever-more mainstream, and describes the development of strategies and deployment plans across the spectrum of cloud solutions.

“How to Begin Using Public Cloud Infrastructure as a Service”

Enterprise architecture and technology innovation leaders must avoid overplanning their initial forays into public cloud IaaS. Such plans rarely survive the realities unearthed by running a series of

pilot projects. This research highlights how to begin meaningful pilot projects, which is key to understanding the cloud's true potential, as well as recognizing unexpected impediments.

"3 Ways That Hybrid Cloud for DBMS Will Drive Your Data Management Strategy"

This research shows that enterprises using the cloud will be living in a hybrid deployment world for the foreseeable future. Data and analytics leaders must understand the risks and benefits in using the primary scenarios for hybrid cloud database management systems (DBMSs), and how they align with core use cases and architectures. Among the solutions, enterprises should only adopt multicloud architectures when there is a compelling reason to do so.

"Hype Cycle for Platform as a Service, 2018"

PaaS provides cloud application infrastructure services. It fits between the compute and storage IaaS markets and the software solution (SaaS) markets. Application leaders making decisions about planning, building or deploying cloud-based solutions should use this Hype Cycle for PaaS to assess the viability, risks and opportunities for the technologies and architectures that combine to make up the cloud platform landscape.

"What You Need to Know Before Buying and Deploying Cloud Offerings: A Gartner Trend Insight Report"

As cloud services become the foundation that best enables digital businesses to transform, differentiate and gain a competitive edge, technical professionals must build their competencies for choosing, managing, governing and securing cloud services and tools.

"Evaluation Criteria for Cloud Infrastructure as a Service"

There are numerous choices for cloud IaaS providers today, and choosing the right service for an organization's technical and business needs is critical. This research offers 263 evaluation criteria to use when comparing cloud IaaS providers and making selection decisions.

"Magic Quadrant for Public Cloud Infrastructure Managed Service Providers, Worldwide"

The public cloud infrastructure managed service provider (MSP) market is immature and is experiencing dramatic growth and change. Although most MSPs are small, the past year has seen a sizable increase in demand for their services. The number of vendors has also increased. Traditional hosting, managed services and data center outsourcing (DCO) businesses are being severely disrupted by cloud adoption, and most of the companies engaged in those businesses are pivoting to become cloud MSPs.

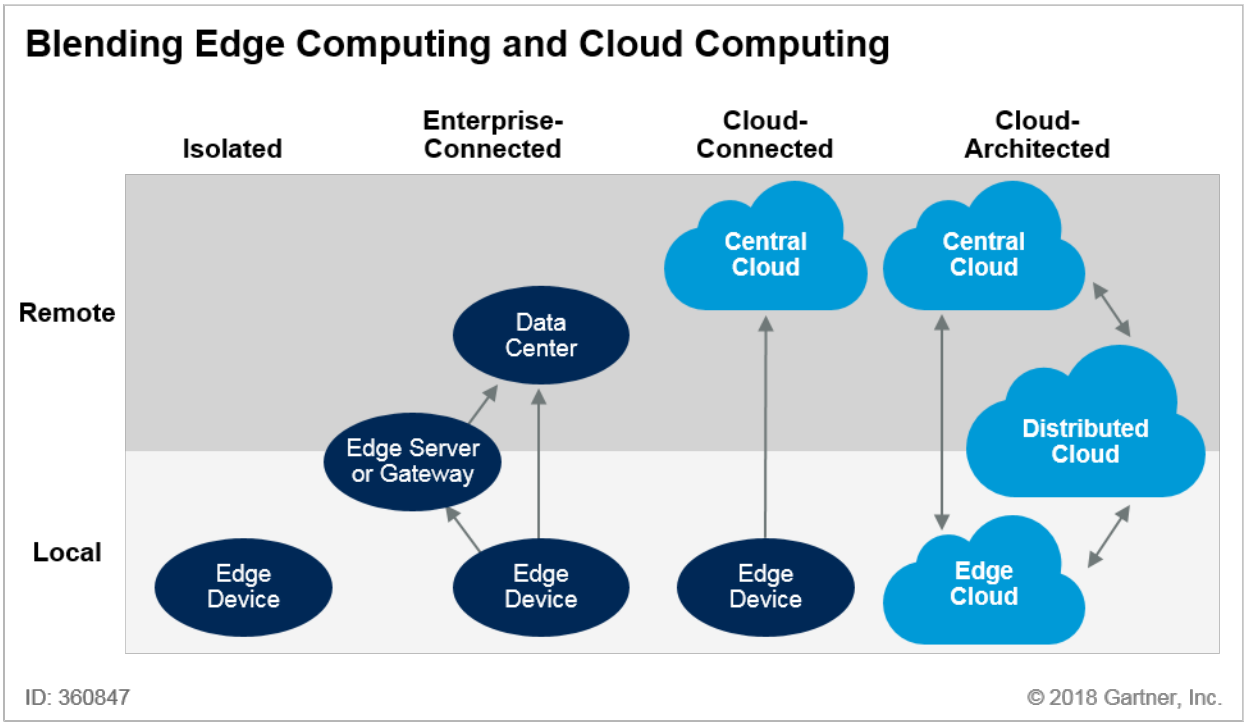
"Critical Capabilities for Public Cloud Infrastructure Managed Service Providers, Worldwide"

The capabilities of MSPs vary widely by use case. Architecture and technology innovation leaders should align their public cloud use cases with optimal provider capabilities to produce agile and reliable applications, lift-and-shift data center moves or strategic DevOps.

## Synergies: How Will Edge and Cloud Evolve Together?

Although the cloud itself does not, by definition, require centralization, the economies of scale promised by the cloud are maximized when operated at hyperscale. Until recently, edge computing was considered unnecessary by cloud vendors and planners, due to modest expectations of the edge and the widely dispersed communications nodes assisting in the delivery of IaaS. However, implementation realities (e.g., the speed of light, the economics of backhauling massive amounts of data and cloud data ingress/egress expenses) have led hyperscalers to conclude that both centralized cloud and distributed edge are necessary (see Figure 8).

Figure 8. Blending Edge Computing and Cloud Computing




Source: Gartner (September 2018)

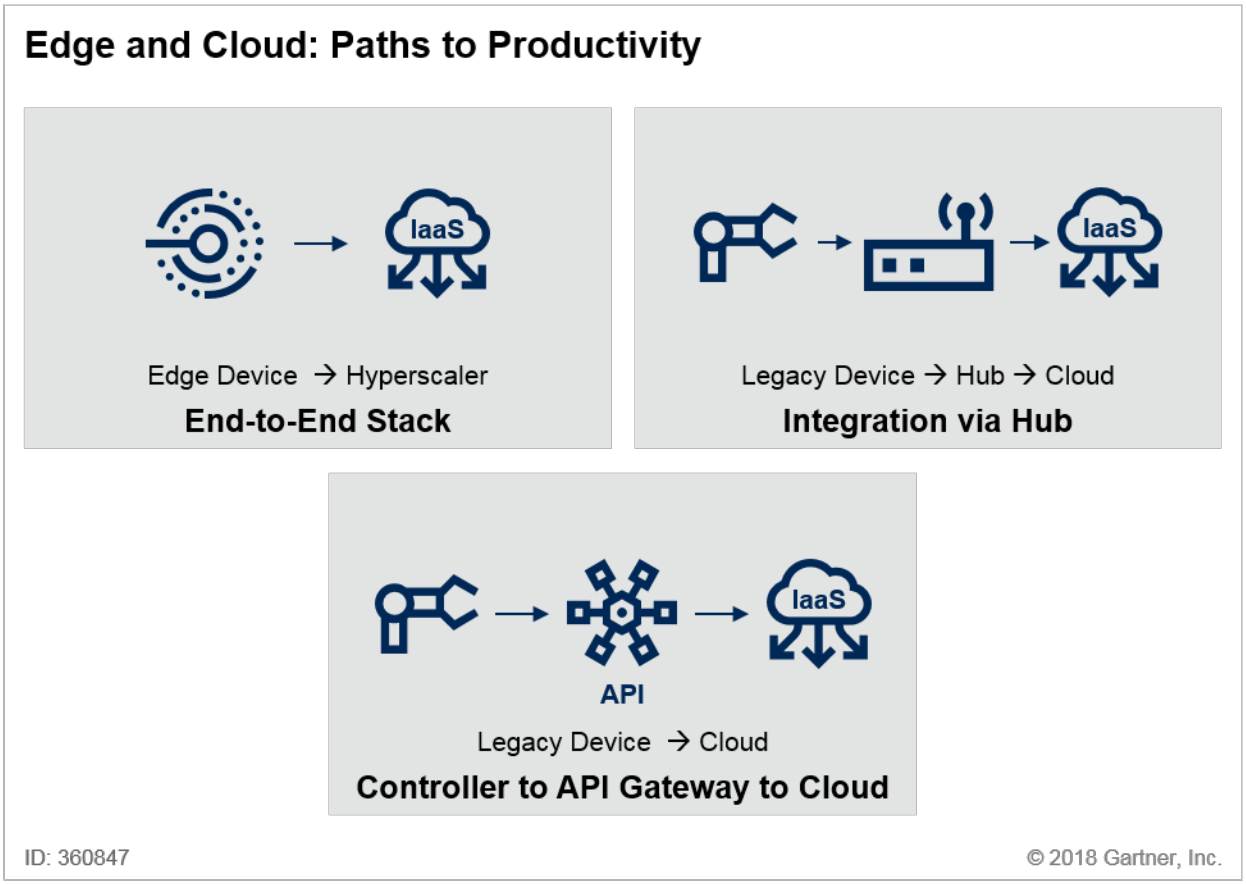
> Implementation realities, such as the speed of light, the economics of backhauling massive amounts of data and cloud data ingress/egress expenses, have led even the hyperscalers to the logical conclusion that centralized cloud and distributed edge are equally necessary.

Gartner estimates that IoT endpoints will reach an installed base of 25.1 billion units by 2021. Much of the current attention on edge computing comes from the need for IoT systems to deliver disconnected or distributed capabilities to the IoT world. Edge computing affects virtually every aspect of the IT landscape; however, IIoT is at the forefront of the trend. IT and OT are converging in

numerous sectors and industries, including healthcare, transportation, defense, energy, aviation, manufacturing, mining, oil and gas, natural resources, telecommunications, and utilities.

These sectors and industries generate large quantities of data that are more efficiently filtered, analyzed and acted on locally. During the next five years, we expect the proportion of edge applications based on new deployments of complete stacks of technology (from edge OS back through specialized hyperscale-provided platform services) to rise dramatically.

Figure 9. Edge and Cloud: Paths to Productivity




Source: Gartner (September 2018)

## Related Research

"Top 10 Strategic Technology Trends for 2018: Cloud to the Edge"

This research provides an overview of the trends that see content, compute and storage resources moving to the edge of the network. Led by the demand for IoT services, it shows how edge and cloud computing are complementary concepts, helping to distribute and work on data in flexible ways that support a growing range of use cases.

"The Future Shape of Edge Computing: Five Imperatives"

This research highlights how latency and determinism, local interactivity, limited autonomy, data and bandwidth, and privacy and security imperatives will help shape how edge use cases are leveraged. Solutions and markets will form around combinations of these imperatives, and you can use them to evaluate the efficacy of possible edge computing solutions.

“Digital Business Will Push Infrastructure to the Edge”

This research discusses the attributes and requirements for digital business, including the use of massive and increasing quantities of data generated at the edge, and the unique ways that edge computing and cloud computing can cooperate to fulfill these requirements.

“Build Your Digital Business Platform Around Data and Analytics”

This research continues the digital business theme, and provides high-level guidance that the real value of digital business is not rooted solely in technology, but in the unique data and analytics capabilities that create business value.

“Digital Business Initiatives Will Require a Hub-Based WAN Edge for Sufficient Agility”

This research highlights an expected fourfold increase in demand for partner interconnects brought about by digital business, and the impact such growth will have on WAN architectures and best practices. It is a great example of the necessity and benefit of edge topology planning as the only feasible solution; however, it does not focus on edge devices or the IoT.

## Related Priorities

Table 1. Related Priorities

| Priority | Focus |
|---|---|
| Cloud Computing | Cloud computing is a critical component of business and IT as next-generation technologies and initiatives (such as digital business, the IoT and artificial intelligence) storm into reality. |
| Accelerating Infrastructure Innovation and Agility | This initiative focuses on Mode 2 of bimodal, which drives innovation as the foundational IT platform for digital businesses. |
| Building and Sustaining Dependable Infrastructure | Building and sustaining dependable infrastructure focuses on what is needed to support mission-critical infrastructure, applications and operations. |
| Build and Market Cloud-Based Offerings | The build and market cloud-based offerings initiative provides guidance on how to identify opportunities and plan, prepare and execute successful cloud offering strategies. |
| Building and Expanding a Digital Business | Digital business is the creation of new business designs by blurring the digital and physical worlds. Digital business involves the interaction of people, businesses and intelligent "things." |

Source: Gartner

## Gartner Analysts Supporting This Trend

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## Related Resources

### Webinars

How Edge Computing Completes Cloud

What Is Edge Computing and Why Should You Care?

Digital Business Will Push Infrastructures to the Edge

### Articles

“Cloud Computing Tops List of Emerging Risks”

“Cloud Computing Enters Its Second Decade”

“Hidden Cloud Growth Opportunities for Technology Service Providers”

“What Edge Computing Means for Infrastructure and Operations Leaders”

## More on This Topic

This is part of an in-depth collection of research. See the collection:

- Research Roundup: Building and Marketing Cloud-Based Offerings — 3Q18

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